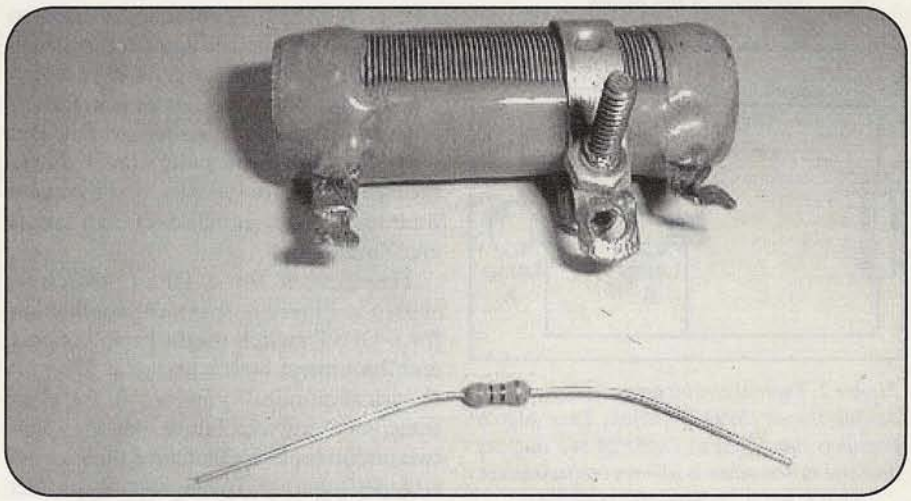
Components and Circuits—Part 1

Several of the questions on the Novice and Technician license exams cover electronic components. This month, Don discusses three of the most basic ones: switches, batteries, and resistors.

Back in the '50s, hams who purchased their equipment at the local amateur radio store were called "appliance operators." If you hadn't built it yourself, or didn't know how to repair your "appliance," you faced an electronic purgatory much like many No-Code Techs face today.

This helps explain why kits were so popular back in those days. If you had a Central Electronics SSB exciter in 1955, your peers knew you had successfully wielded a soldering iron. Whether you "rolled your own," or built a kit, you automatically learned about the electronic components—capacitors, resistors, inductors, connectors, and so forth.



A resistor is one of the basic components of an electronic circuit. Two types are shown here: a low-power carbon-composition resistor in the foreground and a high-power wirewound resistor in the background.

Electronic "Innards"

Most hams have seen the "innards" of an electronic product. Older equipment was a maze of wires and mysterious, colorful shapes. Modern electronic goodies use etched circuit boards with objects that are even more mysterious and colorful, but much smaller and aligned in a more orderly manner. These bits and pieces of electronic trivia are the devices which make the product function and are called *electronic components*.

Components are the ingredients of an *electronic circuit*. By themselves, they do nothing, but, when arranged in a predetermined manner, they can do almost anything you can imagine. They can be laced together by copper wires in a handmade device or by copper circuit traces on an etched circuit board. Many of the same parts found inside ham radio equipment are also used in television receivers, telephone answering machines, stereo receivers; in fact, in everything electronic. They're just arranged differently to perform different functions.

Each piece of electronic equipment has a "roadmap" of how all the parts are connected together. This guide is called a *schematic diagram*. In a schematic, each of the electronic components has a *schematic symbol* which is a standardized representation of the device. Anyone skilled in electronics can look at the schematic and say "that's a resistor"; "that's a transistor"; or "this end of the capacitor is grounded."

In some cases the "roadmap" is drawn to show the physical appearance and location of the components. This is referred to as a *pictorial diagram*.

Switches

Everyone has used a switch. Each time you turn on a light in your house, fire up the television or stereo, or start your car you use a switch. Switches come in many varieties and several are mentioned in the ham radio examination.

A switch has two or more contacts. When they're not connected to each other, no current can flow in a circuit. However, when you move the control for the switch (a lever, knob, or other interface) so that the contacts touch, you complete the circuit. This is what happens when you turn on a light. When the switch is off, the electrical power in your home stops at one of the switch contacts. When you turn on the switch, the circuit is completed and voltage, usually 120 volts AC, is applied to the light.

You can illustrate this while working with voltages that are not harmful. Let's say you touch the two wires from a small flashlight bulb to a flashlight battery. When you do this, the bulb lights up. When you lift either one of the wires, the bulb stops shining. You have just created a switch.

Figure 1 shows a similar arrangement in pictorial diagram form, but I've shown the switch in this and successive draw-

By Donald L. Stoner, W6TNS

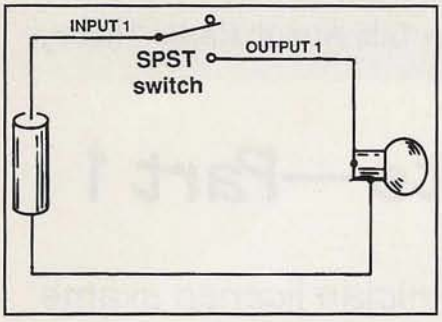


Figure 1. Typical circuit using a single-pole, single-throw (SPST) switch. This switch connects one input to one output and is either off or on. Note the pictorial representation of the battery and lamp, and the schematic representation of the switch.

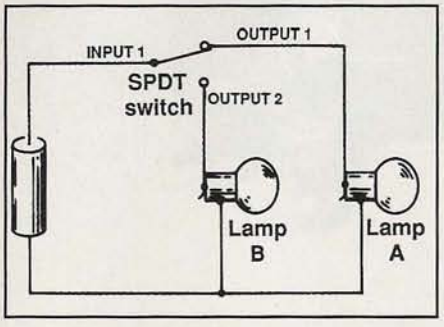


Figure 2. Typical circuit using a single-pole, double-throw (SPDT) switch. This switch connects one input to either of two outputs and one or the other is always on (unless the switch has a "center off" position).

ings in schematic form. One bulb wire is connected to the positive terminal of the battery in series with a switch. The other light bulb wire connects directly to the negative terminal. Since all the parts are in series, you only need to switch one wire to open the circuit and prevent the bulb from illuminating. This type of switch is called a *single-pole, single-throw*, or SPST, switch. *An SPST switch can connect one input with one output.*

Now let's connect the battery wire to the arm contact of a switch with two other contacts, as shown in Figure 2. In one position (up), the battery connects to lamp A and, in the other position (down), the same wire connects to lamp B. The other two lamp wires are connected to the negative end of the battery. When the switch is in the up position, lamp A will illuminate; when you move the switch to the down position, lamp A goes out and lamp B lights up. This type of switch is called a *single-pole* (the arm), *double-throw* (the two contact positions), or SPDT, switch. *A single-pole, double-throw switch can transfer one input to either of two output lines.*

Note that in this diagram one lamp or the other will always be illuminated because there is no *off* or open-circuit position on the switch. Either way you move the switch handle, a bulb is connected to the battery. You'd need an SPDT switch with a *center off* position to extinguish both lamps.

It's possible to use one switch to control two independent circuits at the same time. The circuit to accomplish this is shown in Figure 3. The switch in this instance is called a *double pole* (the arm), *single throw* (one contact position), or DPST. A DPST switch can be used to switch two lines at the same time, one arm to one circuit and the other arm to a second circuit. When the switch is in the off or up position, both lamps are out. But when you move the switch lever down, the two inputs are connected at the same time to the two outputs and both lamps are illuminated.

The symbol for a DPST switch is shown in Figure 3. A typical application for a DPST switch might be to connect and disconnect both wires of a 220-volt electrical circuit. If you look in the electrical panel for your house, you may find two circuit breakers that have their levers strapped together. These probably protect the circuit to your kitchen range. Each of these circuit breakers is an SPST switch, but when two are strapped together, it creates a DPST switch. *A DPST switch can switch two inputs at the same time, one input to one output, and the second input to the other output.*

"Each piece of electronic equipment has a 'roadmap' of how all the parts are connected together. This guide is called a schematic diagram."

You can also control two circuits with a *double-pole, double-throw*, or DPDT, switch. Let's say that you wanted to control two independent sets of lamps at the same time. The circuit to accomplish this is shown in Figure 4. When the switch is in the up position, the power is applied to both lamp 1A and 2A. When you move the switch down, it extinguishes these lamps and transfers the voltage to lamps 1B and 2B and they light up. The schematic symbol for DPDT switch is also shown in Figure 4. *A DPDT switch can transfer two inputs at the same time, each input either of two outputs.*

Batteries

A battery always has a positive and a negative terminal. The symbol for a battery is not a round cylinder with two terminals as shown in the previous illustrations. This pictorial drawing was just a representation to illustrate a familiar object. The schematic representation of a single-cell battery is shown in Figure 5. The voltage of a single-cell battery is between 1.3 and 2.2 volts depending on what type of chemical is used inside.

To be perfectly correct, by definition, a battery consists of two or more cells, but we usually call even the single-cell device a battery, as I did in the previous paragraph. If you need more voltage, several cells can be strung together in series. The positive terminal of cell 1 would be connected to the negative terminal of cell 2; its positive terminal would be connected to the negative terminal of cell 3 and so on. A common application for this can be found under the hood of your car. The battery that starts your car uses six cells, measuring about 2 volts each to provide a 12-volt battery. The schematic symbol for a multiple cell battery is also shown in Figure 5.

Resistors

One of the most common components found in electronic equipment is a resistor. The most common form of this component is made from carbon, much like the black material that one finds in the center of a pencil. There are four principal types of resistors used in electronics: carbon-composition, carbon-film, metal-film, and wire wound; the schematic representation of a resistor is shown in Figure 6.

The main purpose of resistors is to impede or limit the flow of an electrical current in a circuit, but they also convert electrical energy to heat energy. A common example is found in your kitchen in the form of a toaster. The little wire inside that gets red hot is really nothing more than a resistor. The burner on top of your electric stove is nothing more than a resistor inside a metal tube wound in a spiral fashion. When turned on, electrical energy is converted to heat as it flows through the resistive element.

Since resistors impede the flow of an electrical current, they always produce

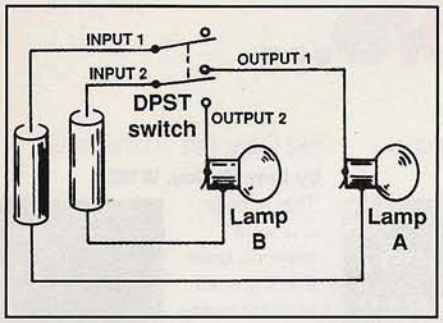


Figure 3. Typical circuit using a double-pole, single-throw (DPST) switch. This switch can control two separate circuits simultaneously, but Input 1 always goes to Output 1, etc.

heat. In some cases, such as in transistor circuits, the heat is so small as to be immeasurable. In other cases, such as the previous kitchen example, the heat generated can be sizable. Because of heating, it's necessary to observe the *wattage rating* of resistors. Carbon composition resistors vary in size from tiny chips of carbon rated at a small fraction of a watt up to about 2 watts. For higher-power applications, wire-wound resistors are used and have ratings from 1 watt up to several hundred watts. Usually the physical size of a resistor is proportional to its power dissipation capability (ability to get rid of heat). By the way, that incandescent light shining above your desk is nothing more than a resistor inside a glass globe. It produces light by glowing white hot; the vacuum inside the bulb keeps it from bursting into flame.

Resistors are available in stepped values from 2.7 ohms up to 22 million ohms (22 megohms or 22M). It is difficult to accurately make a value smaller than 2.7 ohms from carbon, while there is very little use in electronic equipment for resistors that are above 22 megohms.

"Let's say you touch the two wires from a small flashlight bulb to a flashlight battery. When you do this, the bulb lights up. When you lift either one of the wires, the bulb stops shining. You have just created a switch."

Color Coding

The numeric value of resistance is not printed on the resistor. Rather, a coding scheme employing color bands is used. A chart of the color code is shown in Figure 7. The bands of color are usually closer to one end of the resistor, and the band closest to the end is the beginning of the code. The first three color bands are used to indicate the resistance.

It would be impossible to indicate huge numbers like 22 million, so a unique system is used that permits every value of resistor to be shown with only three color bands. The first two bands are numeric indicators, while the third band is a multiplier which indicates the number of zeros following the numeric value. Thus a resistor marked with red-red-orange would have a value of 22 (the two red bands) plus three zeros (orange is three), or 22,000 ohms. If the third band is blue, the resistor value is 22 megohms. For values between 2.7 and 99 ohms, a black band indicates no zeros. If the third band is gold in color, it indicates the numeric values should be divided by 10.

There is a fourth band found on most resistors which indicates its *tolerance*. Because of manufacturing variations, the

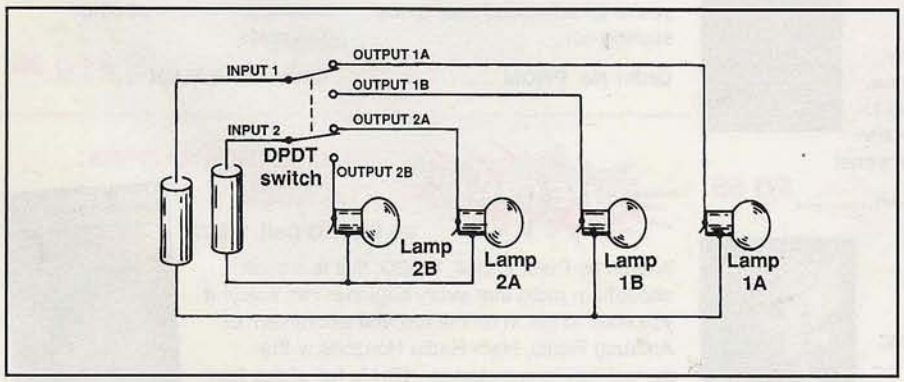


Figure 4. Typical circuit using a double-pole, double-throw (DPDT) switch. This switch controls two separate circuits and *switches one input between two outputs within each circuit.*

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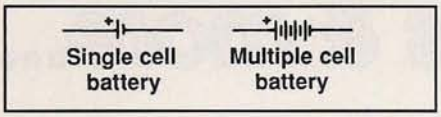

Figure 5. Schematic symbols for a single-cell battery and a multiple-cell battery, respectively. Only the positive (+) end is noted, so it's assumed you'll realize that the other end is negative (-).

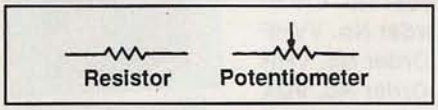

Figure 6. Schematic symbols for a resistor and a potentiometer (variable resistor). See text for discussion of their role in a circuit.

values are seldom exactly as shown. For example, the resistor mentioned above might actually measure 21,000 ohms or 23,000 and still be perfectly acceptable. Except in critical applications, such as filters, this manufacturing variation is normal. But to indicate the tolerance limitation of the resistor, a fourth band (gold or silver) is often added.

For example a 100-ohm resistor (brown-black-brown) might have a 10 percent tolerance as indicated by a fourth silver band. This actual value of the resistor might be anywhere between 90 and 110 ohms. This would be considered a rather poor quality resistor by today's standards. Most resistors in commercial equipment are 5% tolerance. Military equipment almost always uses 1% resistors. A 1% resistor has an extra value-indicating band. In other words, there are three color-coded indicating bands before the multiplier band. A resistor with *no* fourth band has a 20% tolerance.

Occasionally we need to be able to *vary* the resistance in a circuit. Toy train sets usually employ a variable resistor, made of resistance wire with a sliding arm. This device is called a *rheostat* and is used to vary the speed of the locomotive. A smaller version, made of carbon composition material, is called a *potentiometer*. There are contacts at each end of the resistive element and a sliding contact that moves along the element to select the desired resistance. The sliding contact is coupled to a shaft. When the shaft is moved, the resistance is varied. A knob of some sort is usually attached to the shaft. This device is found in most TV sets, stereos, etc., and is called the *volume control*. The schematic representation of a potentiometer is also shown in Figure 6.

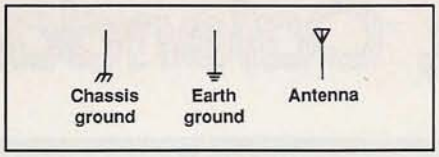

Figure 8. Schematic symbols, respectively, for chassis ground, earth ground (see text for the difference), and antenna.

Antenna and Ground

There are a few miscellaneous circuit symbols that you should be aware of since you may be asked questions about them on your Novice/Technician test. These are the symbols for antenna and ground.

As I'm sure you are aware, the purpose of an antenna is to intercept or radiate radio frequency energy. The symbol for an antenna is shown in Figure 8 along with two other common schematic designators: chassis and earth *ground*.

Earth ground is one of the most common symbols you will find on a schematic. In most pieces of electronic equipment, one end of the power source (usually the negative end) is common to all circuits in the device. Rather than complicate the schematic by showing a common wire running all over the place, things which connect to this point are indicated by a ground symbol. In older equipment, this common point was usually the metal chassis upon which the circuit was constructed. This is referred to as the *chassis ground* or *common ground*.

Today, few pieces of electronic equipment use a metal chassis for the common ground. A transistor radio, for example, uses one or more plastic circuit boards, all contained inside a plastic enclosure. Even a large VCR in a metal case confines its "chassis ground" to a common length of metal foil running around the many circuit boards found inside. The term is, therefore, a little misleading. *A common ground simply means the end of the circuit that is common to most parts in the circuit.*

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For example, in Figure 2, note the lamp connections that connect to the lower end of the battery. These three points could all be connected to a metal chassis (rather than wired together) and the circuit would work exactly as explained earlier. In Figure 2, this point could be labeled common ground.

Obviously, you don't have to go outside and drive metal stakes into the ground to make the circuit work. But occasionally we *do* need to signify an outside earth ground. As an example, all your ham radio equipment that connects to an outside antenna should also connect to an *earth ground*. A schematic showing this would use the earth ground symbol shown in Figure 8.

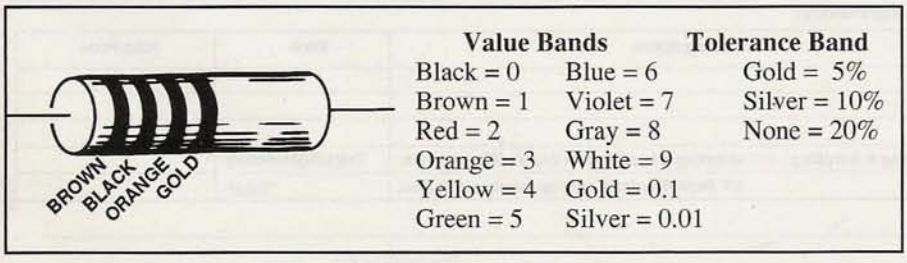

Figure 7. The value of a resistor can be determined by reading the color code imprinted on it. Generally, the first three bands are "value" bands, and the fourth band indicates the resistor's "tolerance," or level of precision. The brown, black and orange bands identify this as a 10K (10,000) ohm resistor (1,0, three 0s), and the fourth, gold band says the actual value is within 5% of 10,000 ohms (9,500 to 10,500 ohms), precise enough for most applications.

We're at Capacity

That's it for this month. In my next column we'll discuss two other fascinating components called capacitors and inductors. Until then,

73, Don, W6TNS.

Components and Circuits—Part 2

In this second half of a two-part article, W6TNS talks about capacitors and inductors. After reading both last month's and this month's columns, you should have a better understanding of the component questions on the Novice/Technician test.

Capacitors are found in virtually every electronic product and are one of the most useful components in the electronic stew we call a circuit. About the time that I was a teenager, capacitors were called "condensers." Then, I guess to avoid confusing condensers with the evaporator part of an air conditioner, the "powers that be" substituted the term "capacitors."

In its most basic form, a capacitor consists of two plates or electrodes separated by what is called a *dielectric* material (see Figure 1). The dielectric is a type of insulator that can *store* an electric charge. Typical dielectrics include air, mica; plastic, paper soaked in an electrolytic solution, and various ceramic materials. For larger values, strips of tinfoil, separated by a paper or plastic dielectric, are rolled into a compact form. Sometimes a metallic substance is evaporated on the dielectric to make a capacitor. Whatever is used, the dielectric material has a significant effect on the value of the capacitor. Figure 1 also shows the schematic (symbolic) representation of a capacitor. Note that the plates can be made in any shape or size.

You'll Get a Charge out of This!

The most useful characteristic of a capacitor is its ability to hold an electrical charge. I'm not sure what they teach in high school science classes today, but my instructor introduced me to capacitors in the form of a Leyden jar. This was composed of a glass jar with an insulating stopper in the top. Going through the center of the insulator was a metal rod. The end of the rod on the outside of the jar had a ball on it, and the other end was immersed in an electrolytic solution inside the jar. The outside surface of the jar was lined with metal foil, which formed the other "plate" of the capacitor. When you applied a static electricity charge to the ball, it would be stored in the dielectric. Then, to illustrate the point that it retained a charge, the teacher would touch the ball to someone who immediately received a memorable jolt as the stored electricity was released.

There is a modern day equivalent of the Leyden jar. It's the picture tube inside your television set. The tube is coated both inside and out with a conductive material. The dielectric is the glass between the two metallic surfaces. When you turn on the TV, many thousand of volts are applied to the tube. Even hours after the set is turned off, the charge remains. ***Never, ever*** *touch that red wire that clips on to the side of the TV tube or you will get a painful (and possibly* ***lethal****) demonstration of how a capacitor holds a charge.*

While I was writing this, nature provided another example of a capacitor. I was jolted out of my computerized trance when a bolt of lightning struck a building less than a mile away. The cloud traveling over the area was highly charged and represented one plate of a capacitor. The Earth was the other conductive "plate," and the air between these two objects was the dielectric. When the charge on the cloud reached the *breakdown point* of the dielectric (the point at which the insulating properties of a material are overcome and it becomes a conductor), a bolt of lightning was released which discharged the cloud.

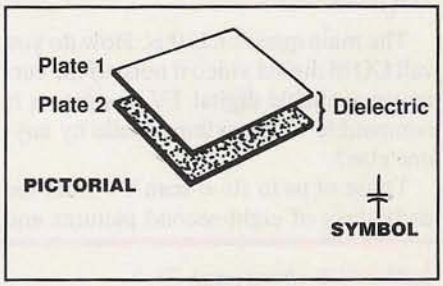

Figure 1. A capacitor consists of two plates of a conducting material, separated by an insulating material known as a dielectric. The dielectric stores and later releases an electrical charge. Also shown here is the schematic symbol for a capacitor.

Measuring Capacitance

The basic unit of capacitance is referred to as the *Farad*. A 1-Farad capacitor will have 1 volt across the capacitor when a charging current of 1 ampere flows for one second. The Farad is an extremely unwieldy value, however, and is seldom seen in electronic equipment. Practical values are the *microfarad* (μF)

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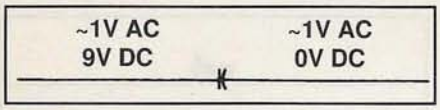


Figure 2. A capacitor in a series circuit will allow AC current to pass unchanged, while blocking DC current. This is quite useful in filtering applications.

which is 10^{-6} Farad, the *nanofarad* (nF or 10^{-9} Farad) and the *picofarad* (pF, which is 10^{-12} Farad).

Capacitance increases as the plates are moved closer together, but this also reduces the voltage breakdown of the dielectric (that's what caused the lightning bolt). How does one get usable values of capacitance in such a tiny component without the plates touching each other? The answer is the dielectric. Capacitor manufacturers don't use air; rather, the dielectric is made of ceramic for small values and plastic for larger values. The dielectric is rated in a *K*-value. Air has a constant or K factor of 1, while some ceramics achieve a K of 30,000.

Uses of Capacitors

Why do we use capacitors in electronic circuits? For one thing, they can be used in a series circuit to block direct current (DC) while passing alternating current. Once a capacitor has been charged, the charge stabilizes. One plate will exhibit a positive charge, for example, but the other plate will not. However, when the value of the charge on the positive plate changes, the changing value will appear on the other plate. We can use this effect to prevent the DC voltage found in one circuit from being passed on to a second circuit. But the changing value of charge impressed on the DC will appear to pass right through the capacitor as shown in Figure 2.

Here's an example: My satellite dish uses a low-noise amplifier at the dish, and voltage is fed to the amplifier via the connecting coaxial cable. In other words, the cable carries both the voltage to power the amplifier in one direction and the signals the dish receives in the other direction. A capacitor is used at the control box to block the DC on the coax (to prevent it from being shorted out), but the signal from the satellite passes through the capacitor to the processing circuitry in the control box.

This same effect can be used to advantage when a capacitor is used *in shunt* with a circuit. One application of this type is the filter capacitor. These are used in a power supply that converts alternating current into direct current. Figure 3 shows a common arrangement used to get rid of an AC signal when it's not wanted. The 9 volts DC might be used to power sensitive electronic circuits. In this case, we want as little as possible of the original AC signal (called "ripple") on the 9-volt circuit. In Figure 3, the AC "goes through" the capacitor and is shorted to ground, but the DC voltage isn't affected.

By the way, filter capacitors used in power supplies almost always are the type described earlier, using rolled up tinfoil separated by paper soaked in an electrolytic solution. As you might suspect, these are called electrolytic capacitors. The symbol is shown in Figure 4. Note the polarity marks added to the previous capacitor symbol; this type of capacitor is polarized and must be connected with the plus mark to the positive voltage source. If reversed, excessive current will flow inside the capacitor, heating the electrolytic solution until steam forms and...*whamo*!

Variable Capacitors

Capacitors are often used in radio equipment to trim circuits to an exact frequency. Let's say you need a capacitance of exactly 10.32795 pF. You can't use a fixed value of capacitor for this—the manufacturer just could not make so many values of the same item. Thus, some element of the capacitor must be made *variable*.

It's possible to change the size of the plates, the spacing between them, or the interleaving of many plates. You used to see examples of the latter in radios up until the 1980s, or so. The multiplate variable capacitor was used to select the station being received by the radio. Modern radios use a *variable capacitor semiconductor diode* to do the same thing. The symbol representing a variable capacitor is also shown in Figure 4.

Introducing Inductors

The characteristics of an inductor are just the opposite of a capacitor. A capacitor stores energy in an electric or electrostatic field. But an inductor accomplishes the same thing by storing energy in an electromagnetic field.

Every electronic product contains inductors, since every wire or length of copper foil on a printed circuit board exhibits a small amount of inductance. In some cases, such as long copper traces on the "mother board" for a high-speed computer, this is undesirable. But in most cases we purposely use inductors to achieve some result.

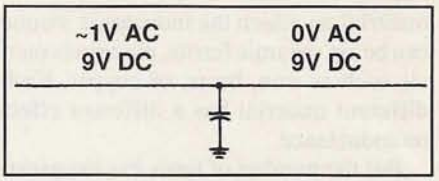


Figure 3. In a "shunt" circuit, the AC current will be "shunted" to ground by passing through the capacitor while the DC current will continue on into the rest of the circuit (this is one way to remove traces of AC from what should be a DC-only current).

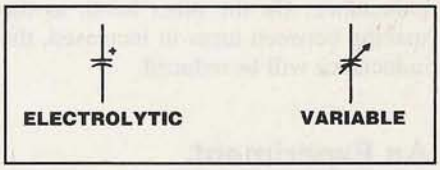


Figure 4. Two specialized types of capacitors are electrolytic and variable capacitors. Their symbols are shown here. See text for discussion of their use in circuits.

If a piece of wire is formed into a coil, its inductance value rises dramatically. The material the coil is wound on is known as the *core*. Wound in this manner, wire takes on the properties of an inductor or coil. See Figure 5 for the symbol for an inductor.

Farad, Meet Henry

The unit of inductance is called the *Henry*. But, like the Farad, this is a very large value. Inductors are more often rated in *millihenries* (mH) or *microhenries* (μH). Several parameters affect the exact value of inductance, including the core diameter, the length of the core and the number of turns used to make the coil. The spacing between turns of wire in the coil also affects the inductance. The core

Figure 5. These are schematic symbols for inductors, whose functions, in many ways, are opposite to those of capacitors. See other diagrams and text for explanations.

material on which the inductor is wound can be air, ceramic ferrite, or various metals such as iron, brass, or copper. Each different material has a different effect on inductance.

But the number of turns has the greatest effect. As the number of turns is doubled, and other factors remain the same, the value of inductance will increase by four. Other factors influencing inductance values include the coil diameter and the spacing between the turns. The larger the diameter of the coil, the greater the inductance. On the other hand, as the spacing between turns in increased, the inductance will be reduced.

An Experiment

When a current is passed through an inductor, lines of force are created. You can demonstrate this by winding some wire on a steel nail. Connect the two wire ends to a flashlight battery and the electromagnet you have just created will attract and hold steel objects like paper clips. The intensity of the electromagnetic field is affected by the same factors that control inductance. Picking up steel objects is not a unique property; any magnet will do this. What is unique is the ability of an inductor to store energy in its magnetic field.

Another property of inductors is that they oppose the flow of alternating current—just the opposite of a capacitor. When an inductor is connected to a source of DC voltage (a battery, for example), the lines of force expand from the coil. But in doing so, the expanding lines cut through the turns of the coil and induce a current flow in the coil. However, this current flow is exactly *opposite* from the current caused by the battery. Thus, there's an opposition to current flow in the inductor which is actually created *by* the current flow in the inductor.

Eventually the DC current flow reaches a maximum, the lines of force stop expanding and no opposition current is created. When this happens, the current flow through the inductor is limited only by its DC resistance. However, when you disconnect the battery, the lines of force around the inductor collapse and induce the stored voltage in the inductor. If you happen to be holding the wire ends of an inductor at this instant (and it has sufficient inductance), it can cause a shock from the collapsing field. This is the principle on which an ignition spark coil works in your car.

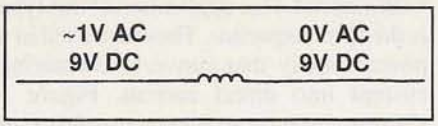


Figure 6. An inductor in a series circuit will pass DC current and block AC current. This is exactly opposite of what a capacitor will do in the same spot.

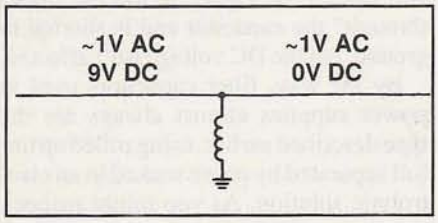


Figure 7. Using an inductor in a "shunt" circuit allows the DC current to pass through the inductor to ground while the AC current continues on into the rest of the circuit. Again, this is opposite of a capacitor's function in this circuit.

An inductor works exactly the opposite of a capacitor in series and parallel circuits. Let's modify the earlier drawings by substituting inductors for the capacitors. The revised circuit is shown in Figures 6 and 7. Let's apply DC, with an AC signal impressed on it, to the inductor. Now the DC has no trouble passing through the inductor since it is a steady value and the lines of force created by in are not changing. The AC signal, on the other hand is varying, causing expanding and contracting lines of force (because of the alternations) which are opposed by the inductor. Thus, on the output side of the inductor the DC is unchanged and passes through with ease. But the AC, which was impressed on the DC, is greatly suppressed. The larger the inductor, the greater the suppression of the AC component.

The action of an inductor can also be used in a shunt circuit as shown in Figure 7. Let's impress the same AC voltage on the DC and apply it to the inductor. Now the DC voltage is shorted to ground by the low resistance of the inductor, but the AC signal is relatively unaffected. The larger the inductor, the less the effect on the AC signal.

Variable Inductors

Inductors, just like capacitors, sometimes need to be made variable to achieve the exact values required. The easiest way of accomplishing this is to insert or

Figure 8. Schematic symbol for a variable inductor. These serve similar roles to variable capacitors in tuning the inductance of a circuit to an exact value.

remove a core material. The lines of force can be aided or opposed if a material other than air is used for the core material. For example, if iron is used, the magnetic lines of force are concentrated in the material and the inductance of the coil is increased. The symbolic representation of a variable inductor is shown in Figure 8. Note that the variable inductor symbol may or may not include the solid lines representing a core.

If the core material is brass (usually silver plated to reduce loss in radio frequency circuits), the non-ferrous material impedes the lines of force and the inductance is decreased below its value with an air core. Note that in the case of either an iron or brass core, some losses will be introduced in the inductor, when compared to an air core. Most tunable inductors employ cores of powered iron. A ceramic material called ferrite is also used to greatly increase inductance.

Taking on Toroids

There is one more form of inductor that you should know about and which may be mentioned in your test. If the core is a donut shape cast of powdered material, it's known as a *toroid*. The turns of the inductor are wound on the toroid and virtually all the lines of force are contained *within* the core. It's very difficult to make toroids variable, so they're usually found in filters or other circuits where fixed values of inductors are required. The schematic symbol for a toroid inductor is the same as for the fixed inductor.

Next Month: RF Safety

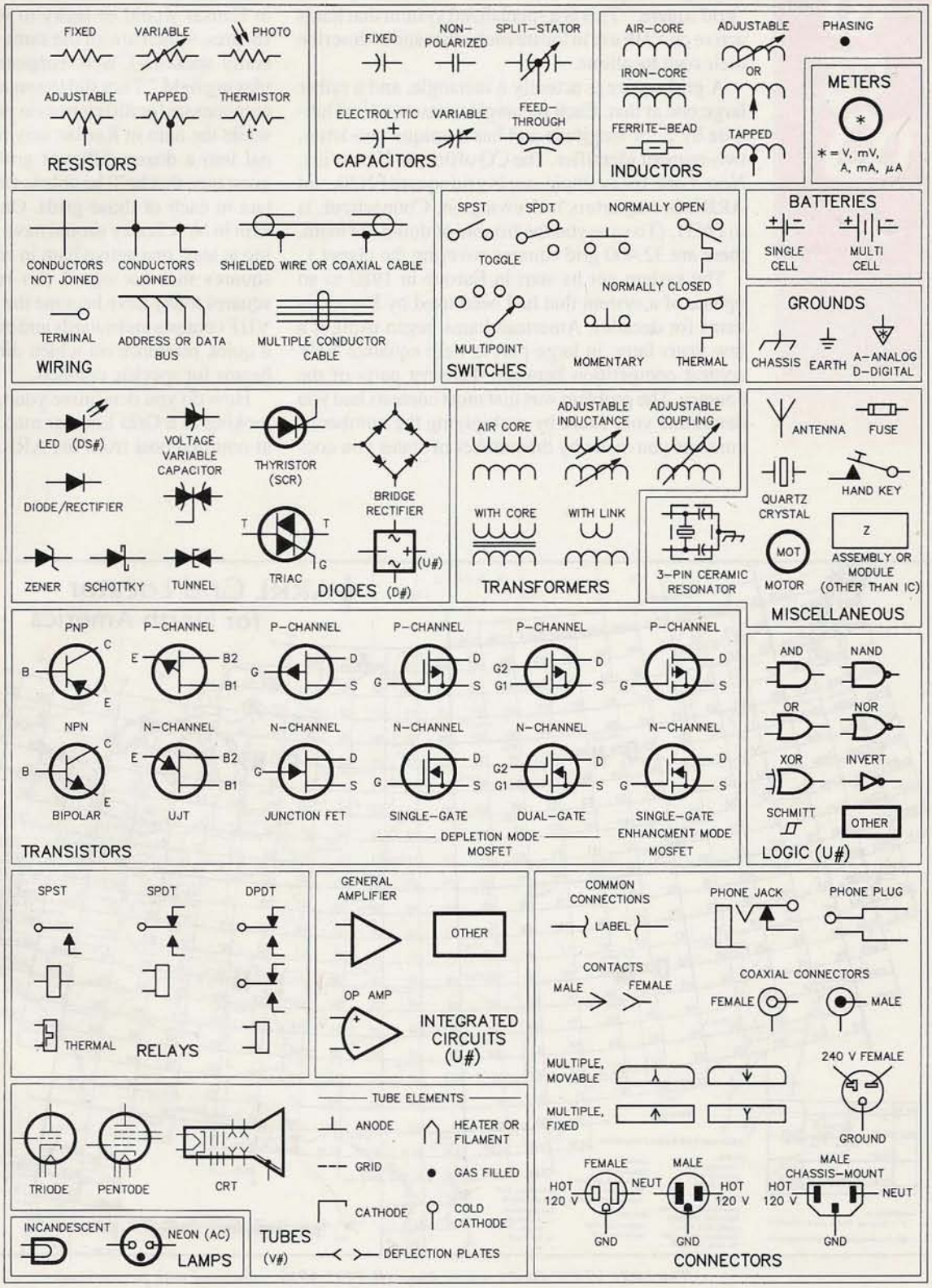
That just about covers the subject of basic circuit components. Next month, we'll tackle the new exam element which was added to ham radio tests earlier this year with questions involving the radiation of radio frequency energy and its potential affect on humans. We'll discuss this next month...In Theory. For now,

73, Don, W6TNS

Basics

Common Schematic Symbols Used in Circuit Diagrams

Building a project from a schematic diagram is always easier if you understand what the various symbols stand for. Here's a guide to the most common ones.



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